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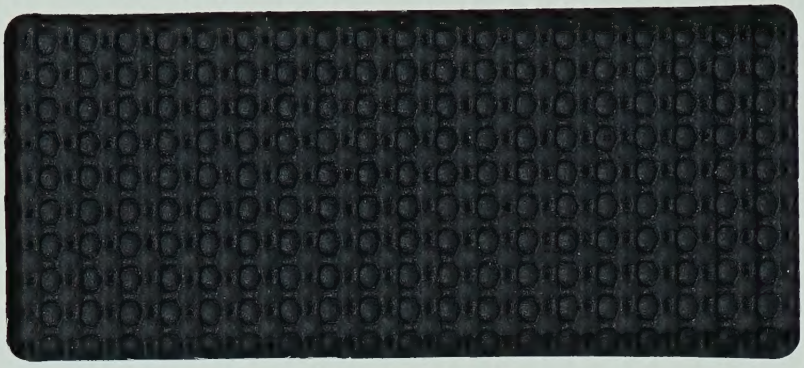
HANS CREEK ICING STUDY: 1979

by

J. C. Anderson and A.W. Gell

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HANS CREEK ICING STUDY: 1979

by

J. C. Anderson and A.W. Gell

Snow and Ice Division
National Hydrology Research Institute
Environment Canada
Ottawa, Ontario
K1A 0E7

Report for the
Northern Roads Environmental Working Group
Department of Indian Affairs and Northern Development

June 1980

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ABSTRACT

An icing is an accumulation of surface ice formed during the winter by successive freezing of sheets of water that has seeped from the ground, from a river, or from a spring. In May 1979, for the third consecutive year, an icing was observed on lower Hans Creek, N.W.T., just upstream of the proposed Inuvik-Tuktoyaktuk highway crossing ($68^{o}52'N$; $133^{o}31'W$). In late May, there were three distinct zones of icing which encompassed a total area of approximately 11.4×10^4 m^2 of the river channel and flood plain. Across the mid-section of the largest zone, ice thickness at eight locations ranged between 0.69 and 1.14 m. At least three icing mounds had formed within the largest icing zone. Growth history of the icing was investigated by observing fracture surfaces on icing mounds and analyzing the crystal structure of ice cores. No overflow ice was observed at the proposed highway crossing in 1979, but the channel was bankful with bottom-fast ice. Prior to its disappearance, the icing caused streamflow diversion and stage elevation during the spring snowmelt flood.

Snow and Ice Division,
Environment Canada,
OTTAWA, Ontario.
K1A 0E7

June 11, 1980

Mr. P. Ferris,
Northern Environmental Protection Branch,
Dept. of Indian Affairs and Northern Development,
6th Floor, North Tower,
Les Terrasses de la Chaudière,
OTTAWA, Ontario.
K1A 0H4

Dear Mr. Ferris:

Attached is a copy of a report on the Hans Creek icing, Mackenzie Delta region, N.W.T. It is an account of studies undertaken during the 1979 field season. I trust that the report meets with your approval.

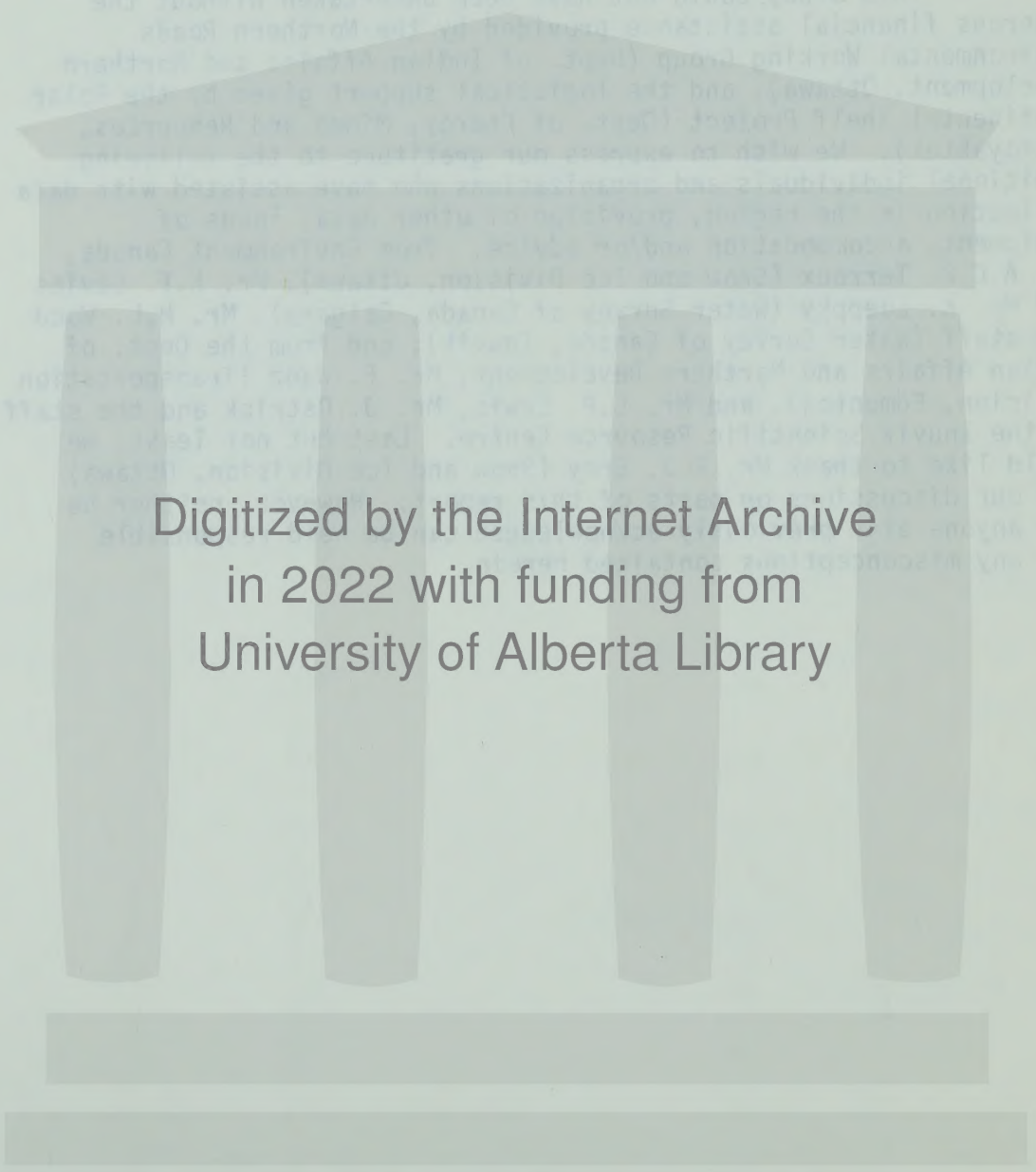
Yours sincerely,

John C. Anderson

John C. Anderson

ACKNOWLEDGEMENTS

This study could not have been undertaken without the generous financial assistance provided by the Northern Roads Environmental Working Group (Dept. of Indian Affairs and Northern Development, Ottawa), and the logistical support given by the Polar Continental Shelf Project (Dept. of Energy, Mines and Resources, Tuktoyaktuk). We wish to express our gratitude to the following additional individuals and organizations who have assisted with data collection in the region, provision of other data, loans of equipment, accommodation and/or advice: from Environment Canada, Mr. A.C.D. Terroux (Snow and Ice Division, Ottawa), Mr. K.F. Davies and Mr. K. Loeppky (Water Survey of Canada, Calgary), Mr. H.L. Wood and staff (Water Survey of Canada, Inuvik); and from the Dept. of Indian Affairs and Northern Development, Mr. F. Janz (Transportation Division, Edmonton), and Mr. C.P. Lewis, Mr. J. Ostrick and the staff of the Inuvik Scientific Resource Centre. Last but not least, we would like to thank Mr. B.J. Grey (Snow and Ice Division, Ottawa) for our discussions on parts of this report. However, neither he nor anyone else previously acknowledged can be held responsible for any misconceptions contained herein.



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HANS CREEK ICING STUDY: 1979

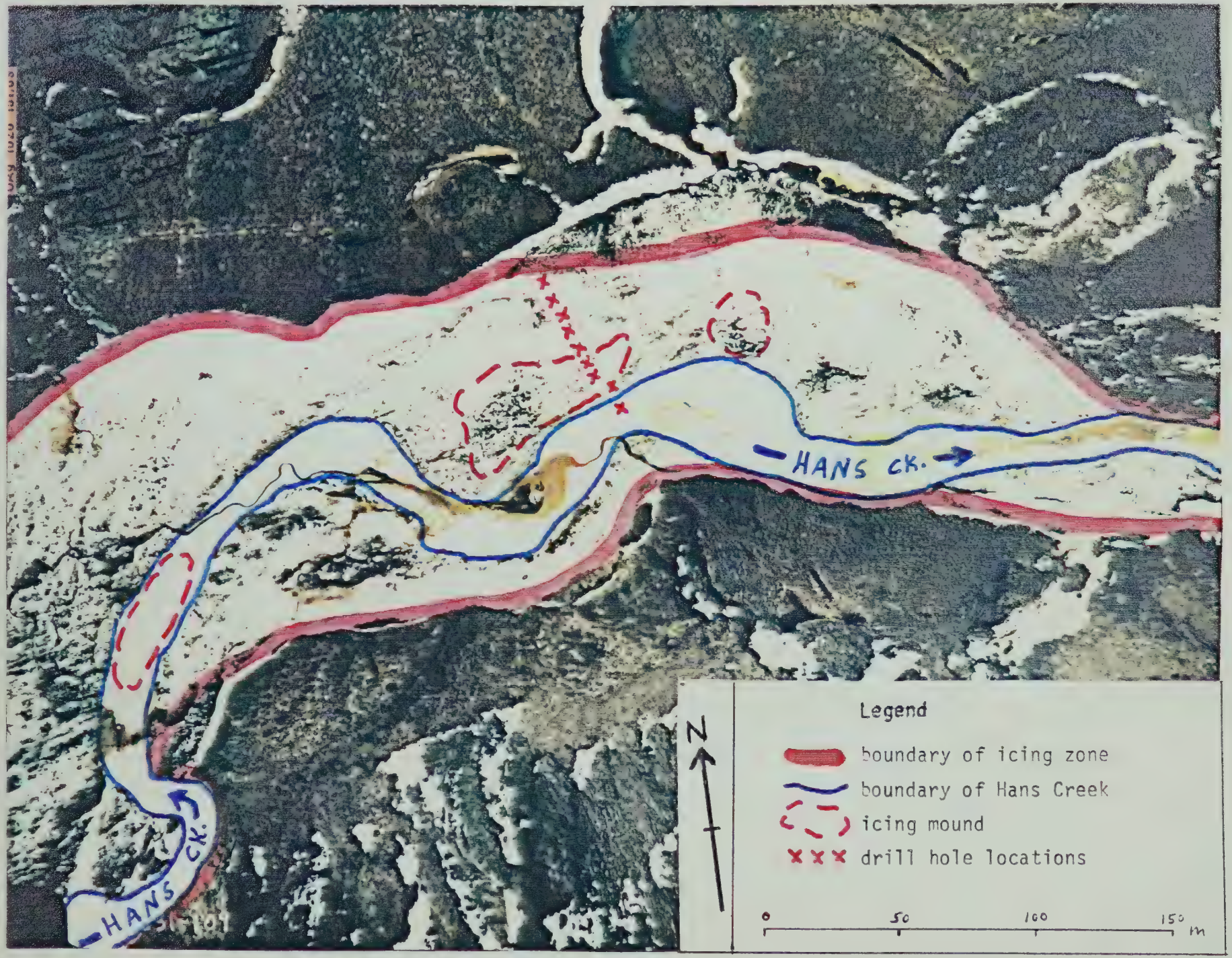
J.C. Anderson and A.W. Gell

A. Introduction: The Nature of Icings

An icing may be defined as "a mass of surface ice formed during the winter by successive freezing of sheets of water that may seep from the ground, from a river, or from a spring". (Muller, 1947, p. 76). Equivalent terms found in the literature are "overflow ice", "aufeis" (German) and "naled" (Russian). The fundamental conditions which promote icing formation are (1) a near-surface impervious layer in the terrain which maintains a high groundwater table, (2) a long, cold freezing season which causes deep seasonal frost penetration and confinement of near-surface groundwater, and (3) a sustained flow of water during the freezing season. The most favourable environments in Canada for icing development are mountainous terrain and land underlain by permafrost. In the former, there may be widespread surface exposure of aquifers above impervious strata. In the latter, the perennial frost may, to varying amounts, obstruct the percolation of groundwater creating an active layer or "suprapermafrost" groundwater zone.

Icings develop from river flow, groundwater seepage, spring flow, or a combination of these sources during the winter season when air temperatures are below 0°C. River icings are most commonly found on reaches which have large width-to-depth ratios, especially where the channels are braided. These sections are more subject to the development of bottom-fast ice early in the winter because of the relative shallowness of flow depth. Bottom-fast ice across a channel confines streamflow to the channel bed and banks. If the hydrostatic pressure becomes high enough, the flow may rise through thermal contraction cracks in the ice cover or rupture the ice and reach the surface. When air temperatures are below 0°C, the overflowing water freezes in sheet-like masses to form an icing. Repetitive overflows can, under extreme circumstances, produce icings 10 to 15 m thick, and outflows may occur at several sites along a river reach, creating icings up to 25 km in length. Although sheet-like in overall appearance, there may be mounds within the icing where locally high hydrostatic pressure has produced upwarping or where repeated outflows have occurred.





PHOTOGRAPH 1. Aerial photograph taken May 27, 1979, of most of icing zone 1, Hans Creek. Note diversion of streamflow from river channel for portions of its path across the icing. (N.A.P.L. photo no. A31231-109; flying height approx. 335m a.s.l.)

Both ground and spring icings have been observed to form in all types of topography, but they are generally more numerous in areas of dramatic change of slope. Ground icings result from water seeping to the land surface in response to high hydrostatic and/or cryostatic pressure. The form of the icing may vary considerably in response to topographic and other factors.

Spring icings share greater similarity in appearance than do ground icings. They are characteristically broad, flat and elongate in the downslope direction, and may have associated icing mounds.

B. Survey of Icing Distribution, Hans Creek, 1979

Initial observations on May 5 confirmed the recurrence of an icing on lower Hans Creek, similar to that seen in the spring of 1977 and 1978. Aerial photographs of the valley taken on May 27 (flying height approximately 335 m a.s.l.) showed three distinct zones of icing between the Water Survey of Canada water level recorder site and the proposed Inuvik-Tuktoyaktuk highway crossing (Figure 1). Total area covered by the three segments was approximately 11.4×10^4 m^2, the areas of individual segments decreasing in the downstream direction (Table 1). Eighty percent of the icing surface area lay beyond the river channel boundaries. Portions of icing zone 1 are shown in Photographs 1 and 2; part of icing zone 2, centred on the Inuvik-Tuktoyaktuk power line is shown in Photograph 3. Bottom-fast ice was present in Hans Creek channel at the proposed highway crossing, but there was no evidence of overflow icing.

Within zone 1, there were at least three large icing mounds, one in the river channel, the others in the flood plain (Photographs 1 and 4). Mounds in the flood plain were formed as a result of uplift caused by the freezing of saturated alluvium.

Variation of icing thickness was studied by drilling nine holes through the ice in a line across the mid-section of zone 1, on May 12 (Photograph 1; Figure 2). The depth of ice atop the flood plain ranged from 0.69 to 1.14 m, with a mean of 0.89 m. The drill hole in Hans Creek penetrated 1.45 m of bottom-fast ice.

C. Icing Stratigraphy, Structure and Growth History

The internal features of the icing mass were observed on fracture surfaces in mounds; also, samples were extracted by coring the

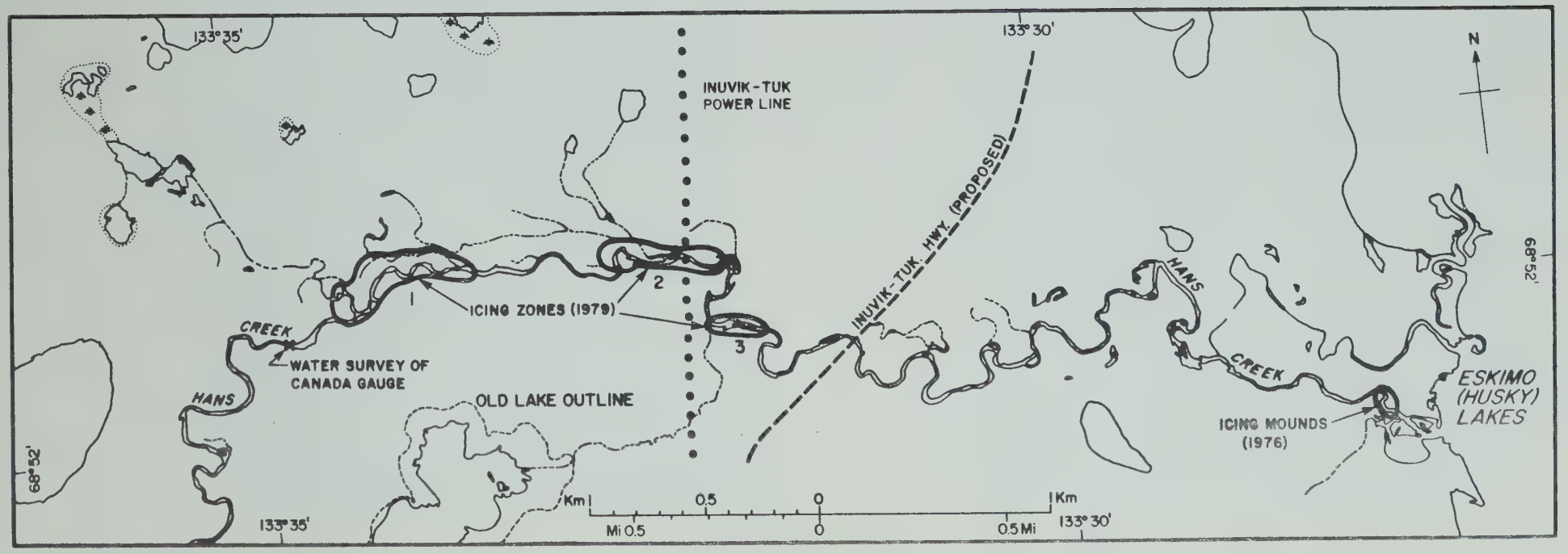


FIGURE 1. Location map, lower Hans Creek area, N.W.T., showing icing zones in relation to proposed Inuvik-Tuktoyaktuk highway crossing.







PHOTOGRAPH 2. View northeast across central portion of icing zone 1, Hans Creek, June 10, 1978. Note the time lapse camera in right foreground, and remnants of large snow drifts in the distance beyond the icing.



PHOTOGRAPH 3. View northeast across icing zone 2, Hans Creek at the Inuvik-Tuktoyaktuk power line crossing, May 27, 1979.

TABLE 1. Approximate dimensions and surface areas of Hans Creek icing zones, May 27, 1979

	Zone 1	Zone 2	Zone 3	Total
Length, in the direction of streamflow (m)	600	500	200	1300
Maximum width (m)	125	80	60	--
Area (m^2)				
- including river channel	7.1×10^4	3.4×10^4	9.0×10^3	11.4×10^4
- excluding river channel	5.8×10^4	2.6×10^4	6.0×10^3	9.0×10^4







PHOTOGRAPH 4. Icing mound within Hans Creek channel, icing zone 1, June 1, 1979. Note cracks within the mound, and diverted streamflow. View is downstream.



PHOTOGRAPH 5. View west across fractured surface of icing mound within icing zone 1, Hans Creek, May 5, 1979. This is the "large icing mound" crossed by the drill hole traverse of May 12 (see Photograph 1 and Figure 2). The ice auger is approximately 1.3m long.

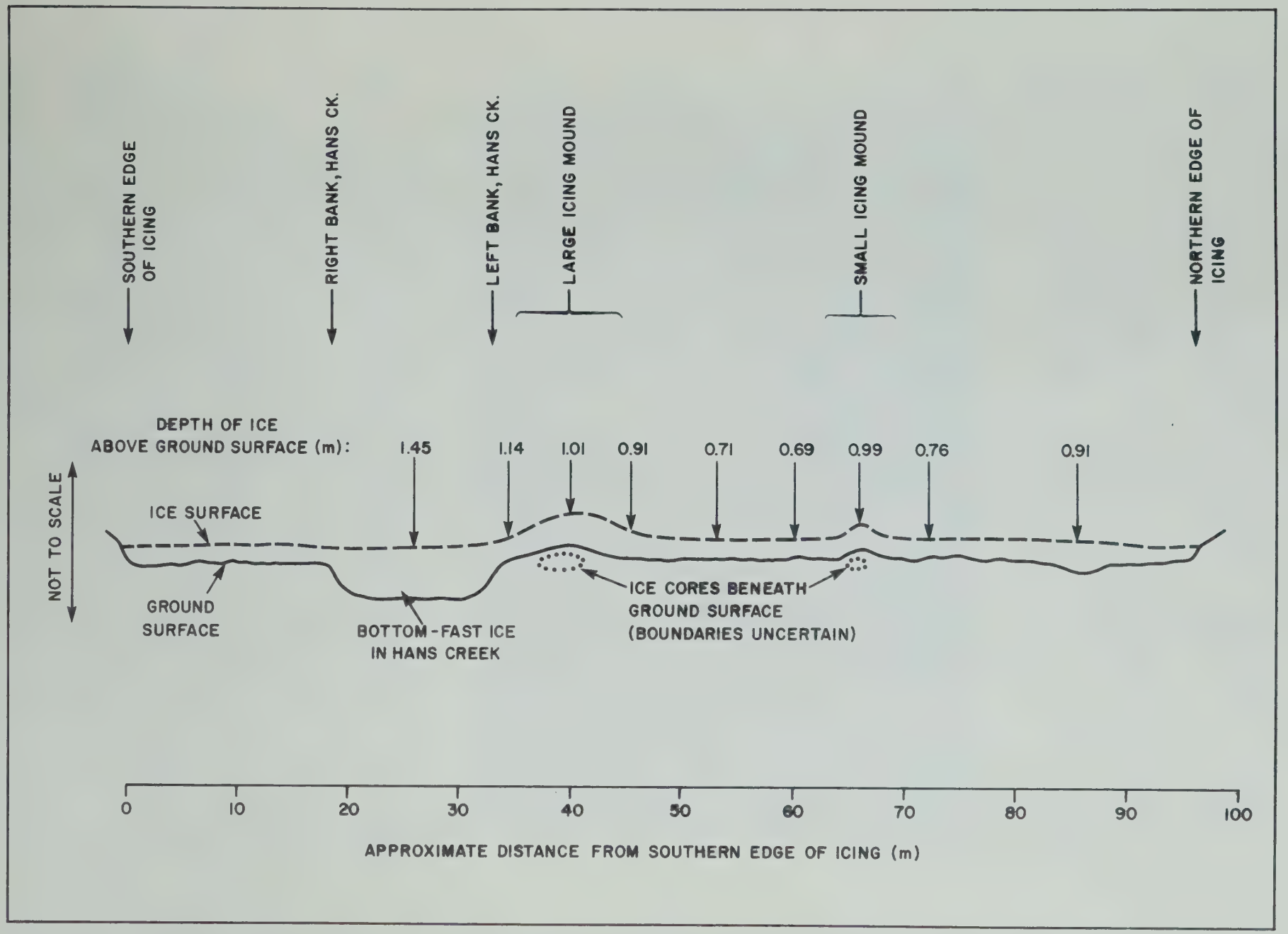
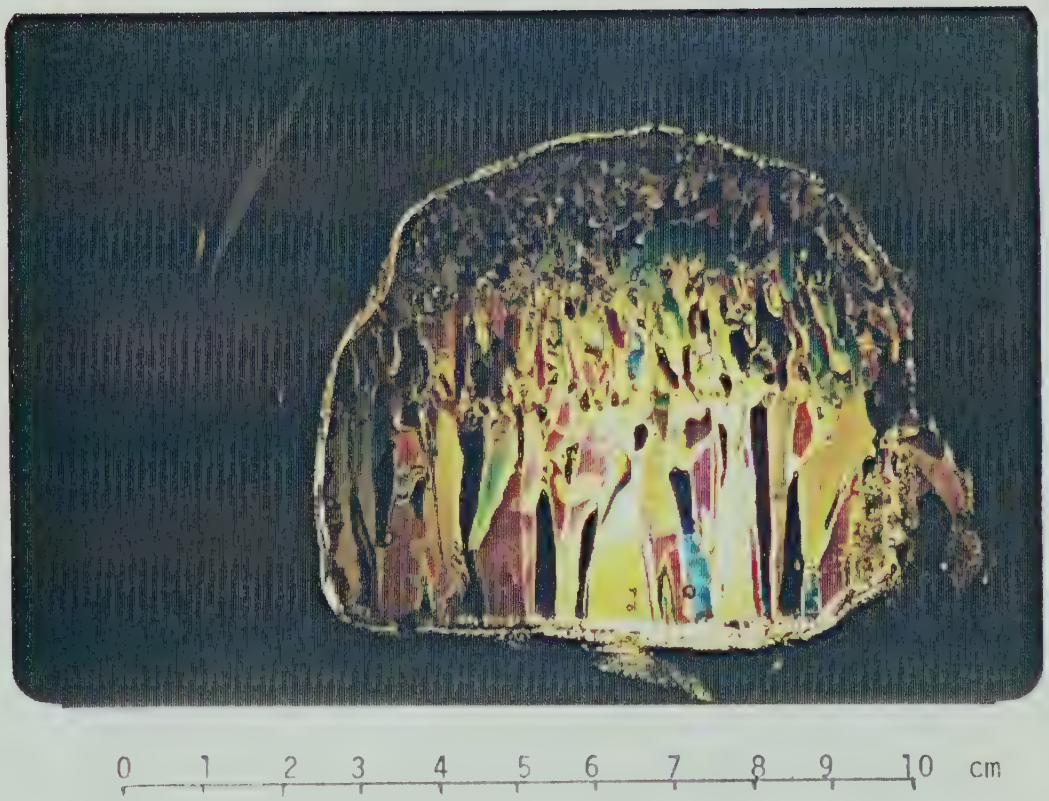


FIGURE 2. Schematic representation of north-south section through central portion of Hans Creek icing zone 1, along drill hole transect shown in Photograph 1.





PHOTOGRAPH 6. Photograph of thin section of ice through crossed polarizing filters. Section is in a vertical plane. Top of section is snow ice, which overlies columnar grained ice. The section is from a core through the "large icing mound" shown in Figure 2 and represents the depth range 34.0 - 40.5cm (see Figure 3). Scale is natural.

large icing mound on the flood plain shown in Photograph 5 and Figure 2. The information was used to elucidate the stratigraphy, structure and growth history of the icing.

Microscopic inspection of the icing cores showed that several periods of ice growth had occurred, as illustrated schematically in Figure 3. Photograph 6 shows a typical change in ice texture and inferred freezing conditions. By way of comparison, a core of bottom-fast ice from Hans Creek channel downstream of the icing zone showed no such differentiation in ice crystal texture (Figure 3).

Fractures in, and cores from the flood plain icing mounds revealed the following gross profile: icing ice, underlain by frozen soil, underlain by another ice mass, of unknown depth. The formation of the mounds was thus attributed to freezing of water beneath the flood plain surface, and the subsequent uplift and fracturing of the overlying materials.

In summary, the processes leading to icing development included:

(a) formation of the primary ice cover on Hans Creek, following commencement of the freezing season;

(b) formation of bottom-fast ice in shallow channel reaches, leading to constriction of streamflow and increase in hydrostatic pressure;

(c) escape of confined water through thermal contraction cracks and pressure-induced ruptures in primary river ice cover, and, possibly, flow of water through ground into flood plain alluvium; freezing of overflow water atop river ice, river banks and adjacent flood plain;

(d) several repetitions of stage (c);

(e) formation of mounds in river channel and adjacent flood plain caused by local freezing of saturated alluvium.

D. Decay of Icing

Time-lapse photography, using a Kodak "Analyst" super-8 camera, was employed to monitor initial decay of the icing in zone 1, from May 20 to June 1. With an unmodified camera, it was possible to vary the time interval between successive photographs, but only to a maximum of 90 seconds. Thus, the longest period of record obtainable using the standard 50-foot film cassette was three and one-half days, and frequent visits to the site were necessary to ensure continuous photography.

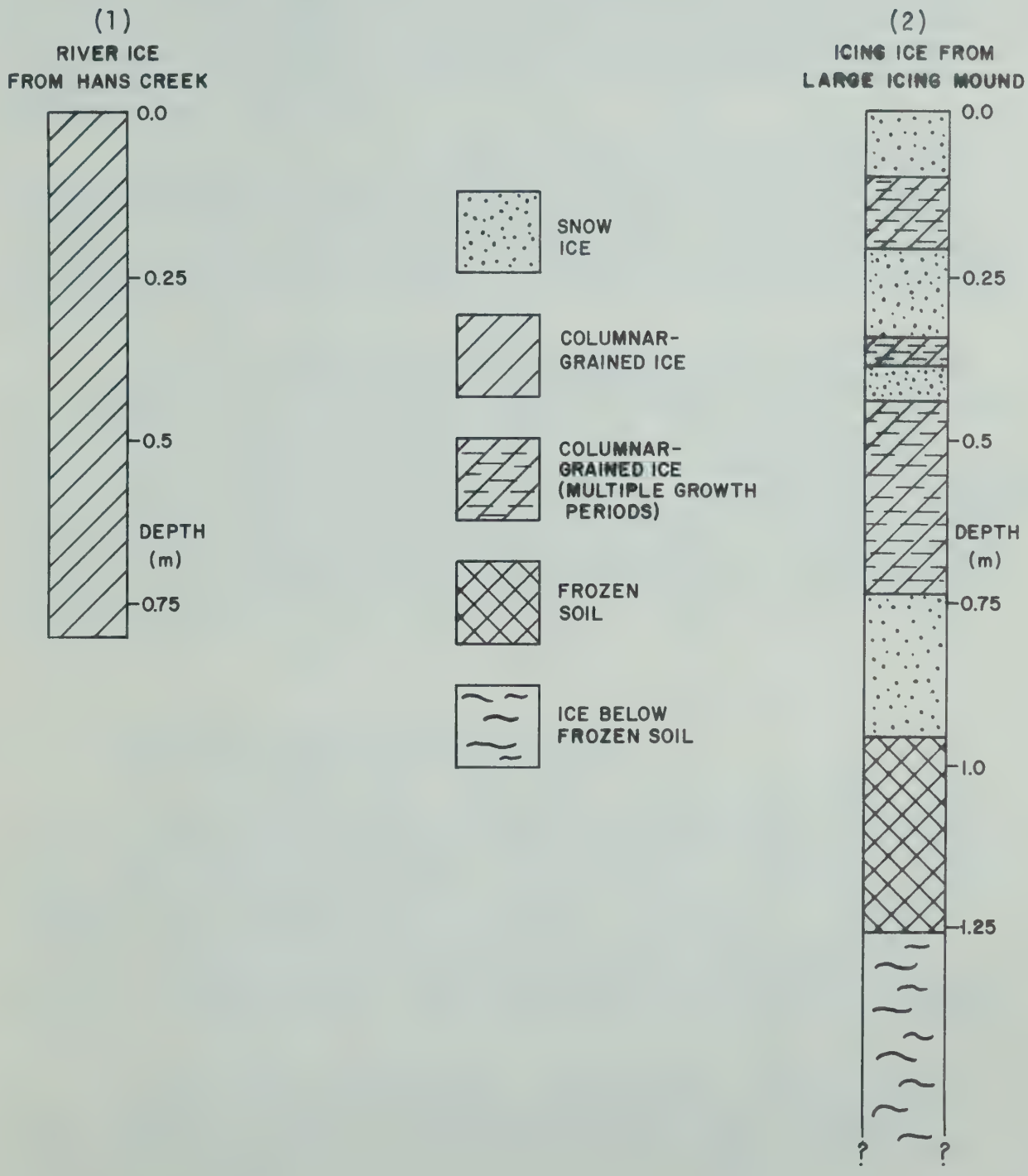


FIGURE 3. Schematic profiles of ice types in cores obtained from (1) Hans Creek near proposed highway crossing, and (2) top of large icing mound crossed on drill hole transect.

As in 1978, the camera was set atop the south-side valley wall, where there was a favourable view of most of the icing zone (Photograph 2). Several visits were made to the camera and icing sites to change film and obtain observations supplementary to the photography. Within its field of view, the camera recorded the more obvious aspects of icing decay such as depletion in areal extent of the ice cover, and the commencement of streamflow through the icing zone. Time-lapse also revealed the diversion of streamflow away from the river channel, onto portions of the flood plain.

During the last half of May, ablation of the icing mass was apparent from the time-lapse record, as more vegetation cover became visible. Ice decay was not monitored after June 1; however, no surface ice was seen in air photos taken on July 6, 1977. In a normal year it can probably be assumed that most, if not all, of the ice would disappear by the end of June.

Time-lapse photography was considered a useful technique for this study. It was decided to have the camera modified to increase the interval between photographs to periods of up to one day. By so doing, the film life would be extended considerably and the camera could be left to operate unattended for months at a time. Additional cameras could be used to provide more detailed, site-specific information (e.g. photography of a staff gauge imbedded in the ice, to record ice ablation). Time-lapse photography might also be used to study icing formation in the freezing season, although reduced light levels (polar night) and the accumulation of snow cover would likely obstruct the view of the icing for much of the winter.

E. Significance for Highway Construction

1. The General Case: Icings may interact with highways in a variety of ways. Overflow ice can partially or completely fill culverts during the freezing season, as has been observed for example in recent years along the Mackenzie Highway near Inuvik, N.W.T. (Table 2). If the situation is not attended to, ice blockage in culverts can lead to upstream ponding during the spring flood, and possibly to overtopping and erosion of the road embankment and/or thawing of permafrost, if present, in the embankment. Not only culverts, but also small bridges have been engulfed by river icings along the Alaska Highway (Clark, 1943).

Roads which traverse river terraces may be subject to overtopping by river icings under certain circumstances. Even if the road is not overtopped, erosion of the embankment may result during the spring flood on account of the elevation of river water levels by the icing.

There may be less channel bed scour beneath an icing during the spring flood event, although the possibility of severe erosion beneath an icing deposit has also been theorized (Carlson, 1979). The potential for severe bed scour is greater around obstructions in the channel, such as bridge piers, where ice tends to be melted and eroded by the flow earlier in the snowmelt flood period.

TABLE 2. Percentage of culvert inlet cross-sectional area occupied by ice immediately prior to spring flood, Mackenzie Highway near Inuvik (source: Anderson, 1980)

Site	Culvert Diameter (m)	% of Inlet Occupied by Ice				
		1976	1977	1978	1979	1980
Km 1512.4 (Mi. 939.8)	1.22	-	25	20	15	20
Km 1516.0 (Mi. 942.0)	1.52	8	100	40	40	30
	1.83	0	50	20	20	10
Km 1519.2 (Mi. 944)	1.22	-	100	30	20	25
Km 1522.4 (Mi. 946)	2.44	8	60	35	25	20
Km 1535.9 (Mi. 954.4)	3.66	2	8	2	10	<2
	1.83	28	60	40	65	0
Km 1561.0 (Mi. 970)	2.44[a]	50e	60	-	40	60
	2.44[b]	45	60e	-	-	40

[a] Town bypass highway crossing

[b] Old airport road crossing

e = Estimate

Modifications to the terrain surface caused by highway construction can produce changes in ground thermal regime or hydraulic conductivity and thus aggravate or even initiate icing development. For example, a bridge shades the river below from direct solar radiation and shelters it from falling snow. This may alter the thermal regime to such an extent that the river ice cover beneath the bridge thickens and restricts flow, causing a river icing to form where previously none had been known to occur. In a similar way, culverts act as heat sinks and can induce icings, as already noted.

Current practice for highway construction in permafrost terrain is to create an end-dumped embankment directly atop the natural terrain surface. The aim is to avoid permafrost degradation beneath the road bed. However, the embankment may compress the underlying soil and reduce its hydraulic conductivity. Permafrost may also aggrade beneath the embankment, to form a dike impervious to suprapermafrost groundwater flow, forcing it to surface. It too few culverts are installed to accommodate this water, culvert blockage from icings may result. Such was the case along the Dempster Highway just east of Ft. McPherson (near Km. 557) during the 1973-74 winter when a groundwater icing grew large enough to overtop the road embankment (van Everdingen, 1978).

2. Hans Creek Site: In 1979, Hans Creek was bankful with bottom-fast ice at the proposed highway crossing site. This ice accumulation effectively elevated the streambed in the same way that an icing does, and caused high water levels during the snowmelt flood while the ice persisted. The nearest icing zone was approximately 700 m upstream, but it must be realized that although icings tend to recur in similar situations from year to year, they need not occur at the same site, or have the same dimensions as in previous years. As well, construction of a highway embankment or bridge may initiate an icing where none had formerly occurred. For these reasons, it is recommended that study of the Hans Creek icing be continued in order to record and understand year-to-year vagaries of icing formation.

F. Summary and Recommendations

In May 1979 for the third consecutive year, an icing was observed on lower Hans Creek in the reach between the Water Survey of Canada water level recorder and the proposed crossing of the Inuvik-Tuktoyaktuk highway. Aerial photography of May 27 revealed three distinct zones of icing which decreased in size in the downstream direction and encompassed approximately 11.4×10^4 m^2 of the river channel and adjacent flood plain in total. Icing mounds had formed in both the river channel and flood plain components of the largest icing zone, and the ice thickness across the mid-section of that zone ranged from 0.69 to 1.14 m in eight holes drilled atop the flood plain. Growth history of the icing was investigated by observing fracture surfaces on icing mounds and analyzing the crystal structure of ice cores.

No overflow ice was observed at the proposed highway crossing in 1979. However, icing extent can vary from one year to the next, and highway construction could possibly induce icing formation at the site. Thus, it is recommended that studies be continued at Hans Creek to determine year-to-year variability of icing formation and character. Future investigations should include (1) aerial photography to define icing extent at the end of the winter growth period, (2) time-lapse photography to monitor icing decay and formation, (3) drilling to determine ice thickness and its variability and (4) analysis of ice crystal characteristics of ice core samples, to study the growth history of the icing.

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